Study on the Delineation of Small Layers and Depositional Micro-Phases in the Qing San Section of the Gaotaizi Formation in Qian'an Oilfield Block 130

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Abstract. The fine isochronous comparison and fine portrayal of sedimentary micro-phases for the stratigraphy of Qian130 block in Qian'an oilfield is a critical problem that needs to be solved in the field nowadays. The target section of the study is the XII Sand Formation in Section III of the Upper Cretaceous Qingshankou Formation, and the oil-bearing formation is the Gaotaizi Oil Formation. Based on field outcrops, cores, logs and other data, a comparative stratigraphic framework of small stratigraphic levels was established and single well phases, continuous well profiles and planar sedimentary phases were studied for the deltaic foreland depositional system of the three sections of the Qingshankou Formation in the Qian'an Oilfield, guided by stratigraphic stratigraphy theory[1-2]. The analysis concludes that the regional structure is located in the northern part of the Changling Depression in the central depressional area of the southern part of the Songliao Basin, where faults are developed. The three sedimentary microphases of the Qingshankou Formation include six microphases: submerged divergent channel, estuarine dam, submerged divergent channel flank, submerged divergent interbay, distant sand dam, and matted sand. Combining the sedimentary micro-phase map of the small layer time unit with the oil formation sandstone thickness map, sand-to-ground ratio map and effective thickness map of the oil formation, the oil and water distribution in the study area is correctly understood to guide the next development of the Qian'an oil field[3-4].

1 Introduction

As shown in Figure 1.The Qian'an formation is located in the northern part of the Changling Depression in the central depressional area of the southern part of the Songliao Basin,and is a pre-Tertiary sedimentary back-slope formation that was influenced once by the Yanshan movement. The Qian 130 well area is on the southern flank of this formation and is part of the nose-like part of the southward extension of the formation. The well area is developed with faults, mostly NNW spreading, a few SN The well area is developed, mostly NNW spreading, with a small amount of SN spreading. The nosedive is further complicated by faults and the tectonic setting sets up the hydrocarbon accumulation in this area.

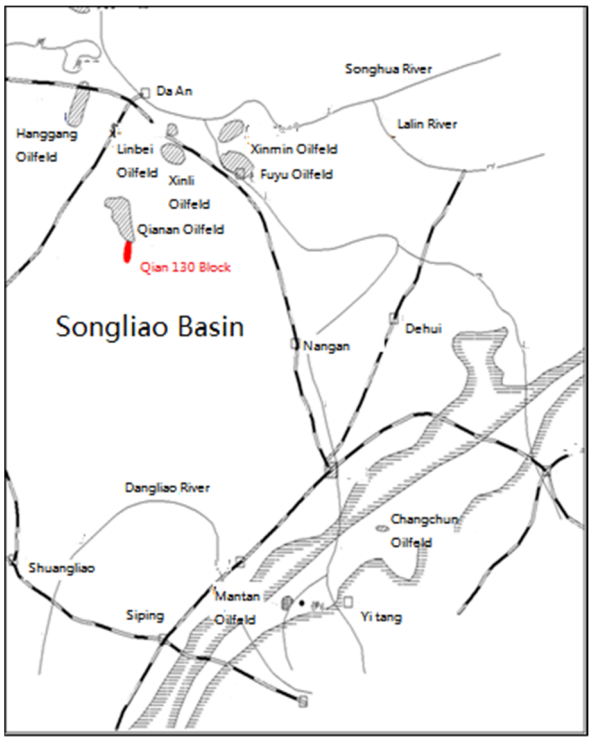

Figure 1 . Map of the location of the Qian 130 area

The Qian 130 block contains an oil-bearing area of 15.2km^2, with geological reserves of 428×10^{4}t and a total of 197 wells. The block has not been systematically

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carried out fine reservoir description work, and the resource potential of the block is not well understood. It is necessary to implement the reservoir development and reserve distribution status through fine reservoir description work, so as to provide scientific basis for the internal comprehensive management of the block and external rolling expansion deployment. The stratigraphic comparison method used in this paper is a high-resolution stratigraphic comparison method, applicable to the terrestrial lake basin sedimentary system, which closes the stratigraphic grid step by step under the control of multi-level marker layers, and establishes a uniform comparative grid of small layers throughout the study area[5]. A fine delineation of the sedimentary micro-phases of the oil-bearing sands by comparing individual high-resolution micro-layers and thereby identifying favorable oil-bearing zones is an important way to enhance recovery[6].

Guided by the stratigraphic stratigraphy theory, I borrowed the old Qian'an division scheme and, on the basis of full respect for the original division scheme, divided the Qing San section of the study area into 12 sand groups with a total of 42 sub-layers, and divided the XII sand group into 38 to 42 with a total of 5 sub-layers.

To date, the sedimentary micro-phases of the various sub-layers in the area have not been analysed and elaborated in detail, nor has the relationship between the sedimentary micro-phases of the various sub-layers and the distribution of oil and water been studied in depth. The degree of recovery and oil-bearing potential of each sub-stratum is unclear, leading to blind exploitation and difficulty in stable production. In response to the above situation, the sedimentary micro-phases of each sub-layer were studied and the types of sedimentary micro-phases and spatial distribution of each sub-layer were dissected in detail. Using the abundant drilling and logging data to subdivide the sedimentary phases, the micro-phase types and distribution patterns of the oil-bearing sand bodies were determined. Based on the different characteristics of oil-water movement in different micro-phases, the oil-water distribution pattern is clarified and the next step of development deployment is proposed.

2 High resolution stratigraphic division and comparison

2.1 Establishment and fine comparison of closed skeleton profiles across the region

Collected and collated various types of information from 197 wells to establish GPTMap, Petrel workings, and preferably selected 31 standard wells in the Qian 130 well area as a skeleton for the overall substratum division. The preferred stratification standard well has complete stratigraphic development, full logging curves, sandstone development, pronounced spallability, vertically divisible and representative of the whole area.

The preferred principles for skeleton closure profiles are as follows: (i) the main profile should be as parallel to the source direction as possible, with the other direction as perpendicular to the source direction as possible; (ii) the profile wells are dense (high contrast reliability); (iii) there are few faults; (iv) the contrast features are relatively obvious; and (v) the stratified standard wells are passed as far as possible. Based on the above principles, a total of 71 skeleton profile wells were selected, including 31 standard wells, forming a 4 vertical and 4 horizontal stratigraphic contrast skeleton closure profile.

2.2 Fine comparison of small layers at each level of datum

For the whole area after comparison of the unified layers, the author concludes that the XII Sand Group is divided into three short-term rotations and five minor layers. There are 2 main sets of marker layers in this study area. One is at the base of the Yao section (the top of the three sections of the Qingshankou Formation), corresponding to three sets of gamma spikes and sonic time difference inflection points (Fig. 2, arrow position at b); and at the base of the three sections of the Qingshankou Formation, where the sonics change from small to large, heavily denticulated and fluted, and rabbittooth-like (Fig. 2, arrow position at d).

Characteristics of the marker layer in the study area: the top of a section of the Nengjiang Formation in the central depressional area, over which large sections of oil shale develop, with a clear peak-like protrusion in the resistivity curve corresponding to the oil shale, which here was formed by starvation deposition during the second largest lake flood in the southern part of the Songliao Basin. This formation is a high resistivity in an overall mudstone low resistivity context, with high values of R2.5 resistivity, and is the most striking stratigraphic contrast feature in the southern part of the basin (Fig. 2, arrow position at a). The Gaotaizi oil formation in the Qian'an area belongs to a typical coastal and shallow lacustrine deltaic depositional environment, and its geographical distribution belongs to the coastal and shallow lacustrine area, where the mudstones are mostly purplish-red, locally grey-green and brown-grey, and the bottom of the XI Sand Group in the Qing San Section can be used as a marker layer in the region, with the R2.5 curve showing a set of four sharp-peaked concentrated sections of chalky mud and muddy siltstone development, which are stable throughout the region. On the other hand, a set of 3-5m purplish-red mudstone is developed at the base of the XI Sand Group, which is stable throughout the region and can be used as a single electrical marker layer at the first level for small layer comparison. (Fig. 2, position of arrow in c).

2.3 Regional skeleton closure profile multiplexed step-by-step closure verification and control fine comparison

Throughout the study area, four main longitudinal profiles parallel to the source direction and four main transverse profiles perpendicular to the source direction were preferentially selected to form a regional skeleton closure profile as a means of controlling the region-wide comparison. A schematic diagram of the region-wide contrast profiles is shown in Figure 3.

The closed skeleton profile comparison is a step-by-step fine-grained comparison and step-by-step closure verification of the "oil formation group → sandstone group → minor formation" on the closed profile. All wells in the skeleton section are scanned first, and 32 standard wells are given as key wells for the comparative stratification. Each oil formation group is started from the key wells in the stratification, and then finely compared and closed in the skeleton section step by step, until all wells are closed. Similarly, the sandstone group is compared until it is closed; then the small layers and sedimentary time units are compared in turn until they are closed, then the comparison of sedimentary time units in the closed skeleton profile is completed.

After completion of the closure skeleton profile comparison, the remaining wells are compared by well row, while at least two wells in each row are on the completed closure skeleton profile, as a timely closure verification for all levels of the boundary of that well row. This results in an area-wide comparison.

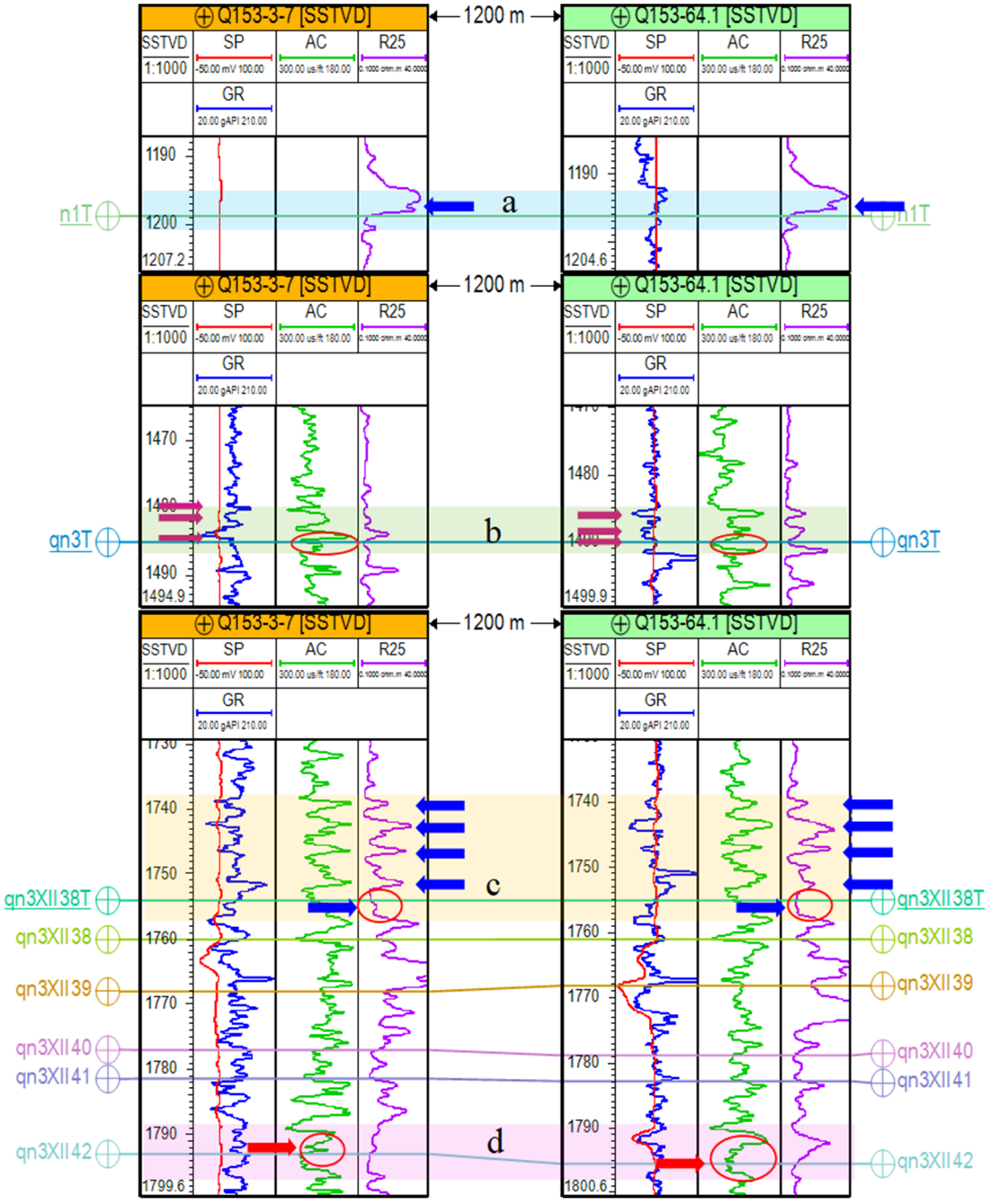


Figure 2. Characteristics of the standard logging curve for the study area's substratum delineation

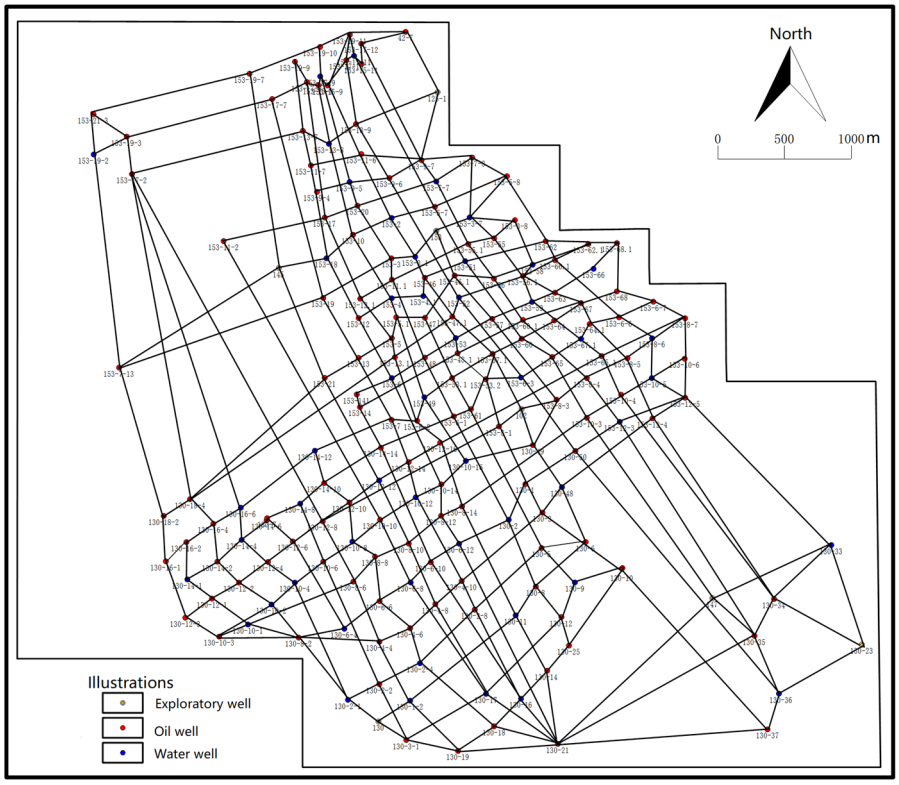


Figure 3. Schematic diagram of comparative profiles across the region

3 Planar spread of sedimentary micro-phases during short-term datum rotation

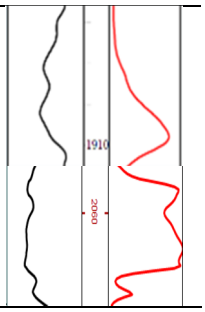
The regional sedimentary phase study concludes that the source of the study area is the southwestern Baokang sedimentary system, and the sedimentary environment in the three sections of the Qingshankou Formation is shallow water deltaic sedimentation in a shallow lakeside context[7]. The sand bodies develop blocky laminations, parallel laminations, undulating laminations, deformation laminations, trough interlacing laminations, oblique laminations and lenticular laminations; the lithology of the study area is relatively fine, mainly siltstone, muddy siltstone, siltstone and mudstone, the siltstone is mainly light grey, the oil-bearing siltstone is mainly brownish red, and the mudstone is darker and purplish red in colour.

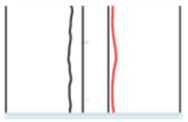
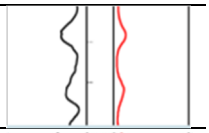
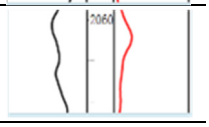
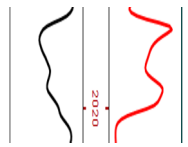
Integrating the regional sedimentary background, phase signatures, core phase analysis, etc., it is concluded that the study area mainly belongs to shallow water deltaic sedimentation and belongs to the shallow water deltaic foreland subphase, which can be subdivided into six microphases based on single well phase analysis: underwater distributary channel, underwater diversion inter channel bay, mouth bay, distal bay, underwater diversion channel side, and sand sheet[8].

3.1 electrofacies analysis

Due to the incomplete core data in the study block, the author selected core wells Qian 188-51 (located in the eastern part of the study area) and Qian 188-32 (located in the eastern part of the study area) in the neighboring area for comprehensive analysis of sedimentary single wells, and established log phase patterns for eight typical sedimentary time units to describe in detail the main characteristics of the sedimentary micro-phases. (Table 1)

Table 1.electrofacies of the XII sand group in the Qing San section of the Qian 130 block

Facies	Subfacies	Microfacies	Lithology	Logging curve patterns	Electrofacies
Delta	Delta-front facies	Underwater distributary channel	Silt	Medium width box,bell-shaped	

		Underwater diversion interchannel bay	Mudstone Argillaceous-siltstone Silty mudstone	Mudstone baseline	
		Underwater diversion channel side	Silt Silty mudstone	Tooth and finger shape	
		Distal bay	Silt Muddy siltstone Silty mudstone	low width funnel type	
		Mouth bay	Silt Muddy siltstone	High width funnel type	
		Sand sheet	Silt Muddy siltstone	Tooth shape	

3.2 Parallel and vertical source directional continuous well deposition microphase study

On the basis of the sedimentary phase analysis of single wells, a preliminary prediction of the distribution characteristics of the source and water system was made based on the sedimentary background of the study area, and four sedimentary micro-phase profiles were established. Two sedimentary profiles were developed in the direction of the source and two in the direction of the cross-cutting source[9].

Parallel source direction continuous well deposition microphase profile 1 from southwest to northeast over well Qian 130-12-1 - Qian 153-6-7, a total of 16 wells. The submerged diversion channel is the dominant microphase, with a few submerged diversion channel flanking microphases present. The channel continuity is good in the parallel source direction, and the 39 minor and 40 minor formations are largely contiguous.

Parallel source directional continuous well sedimentary microphase profile 2 runs from southwest to northeast across well Qian 130-10-1 - Qian 153-8-7, a total of 16 wells. The submerged diversion channel is the main sedimentary microphase, with a few submerged diversion channel flanks and matted sand microphases present, and good overall continuity of the channel in the downstream direction of the source.

Vertical source directional continuous well sedimentary microphase profile 3 runs from northwest to southeast over wells Qian 130-16-6 - Qian 130-4-6, a total of seven wells. The subaqueous divergent channels are the main sedimentary microphases, mostly lenticular in distribution.

The sedimentary microphase profile 4 of the vertical source direction continuous well runs from northwest to southeast over wells Qian 153-17 - Qian 153-12-4, a total of 11 wells. The submerged diversion channel is the main sedimentary microphase with a few submerged diversion channel flanking microphases, and the submerged diversion channel is mostly lenticular in distribution.

3.3 Deposition of microphase planar spreads

The southern part of the study area is better developed than the northern part of the study area due to the influence of the southwestern source supply. To achieve a fine delineation, a sedimentary micro-phase map of the main minor layers in the study area was drawn (Figure 4), and it was found that the higher the accuracy of the comparison, the more significant the guidance for discovering the fine oil and water distribution pattern[10].

It can be seen from the sedimentary micro-phase map of the No. 38 small layer of the XII Sand Group in Qingshan Section 3 that the whole area is developing a deltaic foreland subphase, and the submerged divergent channel sand body is striking from south to north along the direction of the material source, and five submerged divergent channels are developed, which are distributed in a strip or network from southwest to northeast in the plane, among which the wider two channels swing violently and keep bifurcating and converging in many places, the narrower channel in the southwest is 200m, and the wider one can reach 1000m. The narrower channel in the southwest has a width of 200m, while the wider one can reach 1000m at its widest. In the south, the channel is about 1000m wide, with an average sandstone thickness of about 3m and a width-to-thickness ratio of about 320, while the confluent channel at the Qian 130-10-6 well is about 400m wide, with an average sandstone thickness of about 3.8m and a width-to-thickness ratio of about 105.

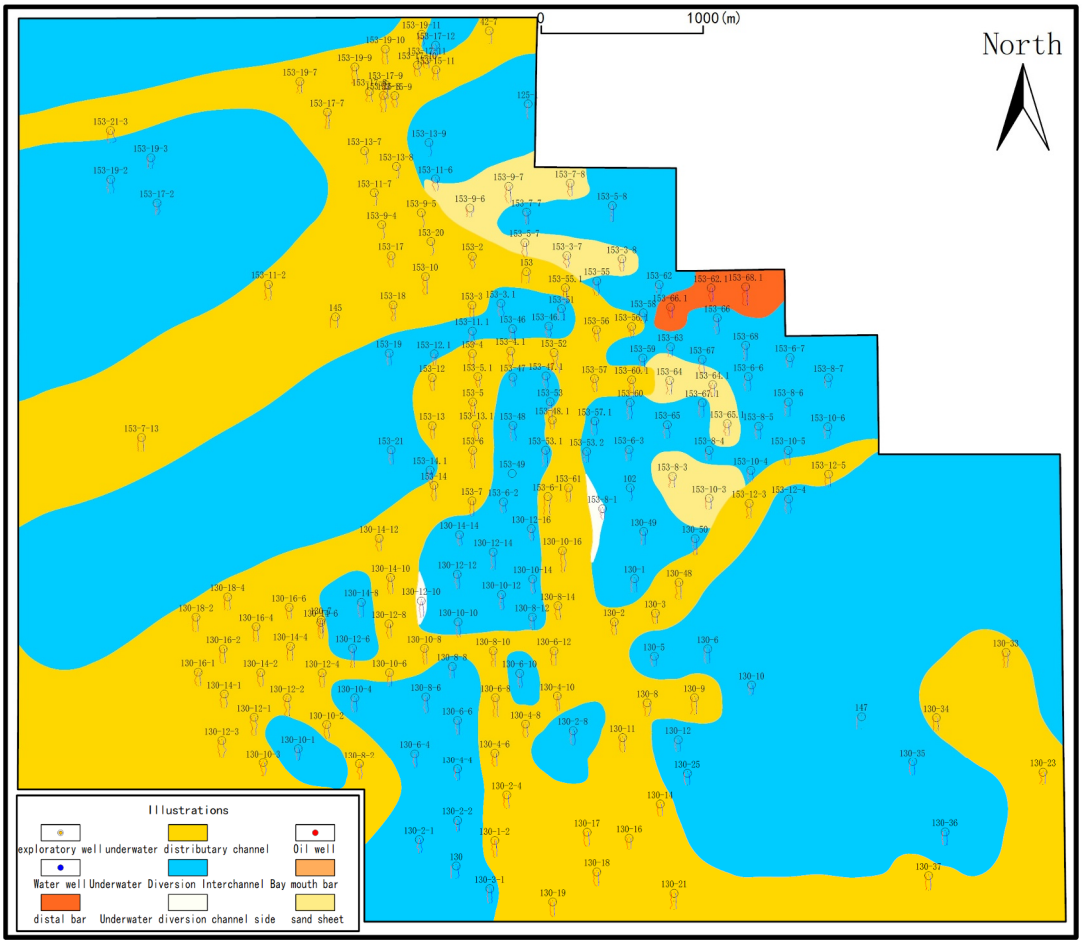


Figure 4 Microphase diagram of the deposition of small layer 38 in Qian 130 block

4 Conclusion

(1) Under the control of a standard layer based on a regional skeletal closure profile, a comprehensive comparison of lake flood surface series combination markers, sedimentation pattern guidance, step-by-step priority approximation and step-by-step closure progressively pushed out to unify small layer comparisons across the region.

(2) The three sections of the Qingshankou Formation in the study area are mainly developed in the deltaic foreland subphase.The sedimentary micro-phase map of the key minor layers was finely delineated, and the connectivity between the sands in the study area was analyzed from section to plane.

(3) The research results can clarify the formation of each sedimentary micro-phase .The next step will be to analyze the potential area, which is of great significance to the fine injection and extraction of the study area.

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